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REPLENISHABLE FOOD SUPPLY ON MARS

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The design team's present objective is to design a facility which will provide an environment to grow plants on the surface of Mars for a continuous supply of food for a ten-member crew. The main focus of the project is the design of a greenhouse. Concentration of the current design effort is on the outer structure, internal layout, and construction methods. The project conducted by undergraduate students at Prairie View A&M University during Fall 1989 and Spring 1990 is presented in this report.

INTRODUCTION

Prairie View A&M University has been participating in the NASA/USRA Advanced Design Program since 1986 and is taking a lead in the design of a surface-based factory on Mars for the production of life-support products.

The Prairie View A&M University students conducted research on "Replenishable Food Supply on Mars" during Fall 1989 and Spring 1990. The names of the students and the report titles are given in Table 1.

Table 1. Reports, 1989-1990.

Name	Title
Fall 1989	
Lisa Armstrong	Control Design for Vegetation on Mars
Raymond Hillis	Design of a Structural Facility on Mars
Garth Daley	Site Selection and Use of High Strength Plastics in Martian Facility
Raymond Hardemon	Layout for Greenhouse
Beverly Dixon	Crop Production Using Hydroponics on Mars
Victor Young	Construction Methods on Mars
Marcus Hines	Air Pressure and Temperature Control
Ogbonna Nnamdi	Food Production Techniques for Mars
Wazier Ajibola	Farming Methods on Mars
Terrance Jackson	Materials for Construction on Mars
Spring 1990	
Terrance Jackson	Construction Materials for Greenhouse on Mars
Charles Nickson	Radiation Shielding for Martian Structures
Noman Alyasin	Soil Investigation for Structural Foundation on Mars
Garth Daley	Soil Moving Device on Mars
Henry Ogoli	Construction of Structures on Mars Using Robots
Aaron Galloway	Mixing System for Hydroponic Cascade
Rosa Brice	Support Structure for a Hydroponic Cascade
Beverly Dixon	Storage Tank and Piping for a Hydroponic System on Mars
Toufic Nabbout	Greenhouse Conveyor Belt for Crop Rotation

FOOD PRODUCTION TECHNIQUES

A special focus of the present effort is to evaluate conventional and unconventional food production systems and plants, as well as to evaluate the potential for utilizing plants that are not currently employed in standard agronomic systems but appear to be useful if transferred to the martian surface environment.

Using simple systems of organic soil supported by native systems supplemented with nitrogen and other essential elements is being considered. Hydroponic growing is under investigation. (In hydroponics, plants are cultivated in water containing dissolved inorganic nutrients, rather than in soil.) The system will consist of a trough in which plants will be grown and a pumping system that will pump nutrient solution into the trough at regular intervals.

DESIGN OF A MARTIAN GREENHOUSE

The greenhouse group's objective is to design a greenhouse pressurized at one atmosphere to allow for human habitation and plant growth. A dome-shaped greenhouse has been selected because of its ease of construction, sturdiness, and adaptability to a variety of construction materials (Fig. 1).

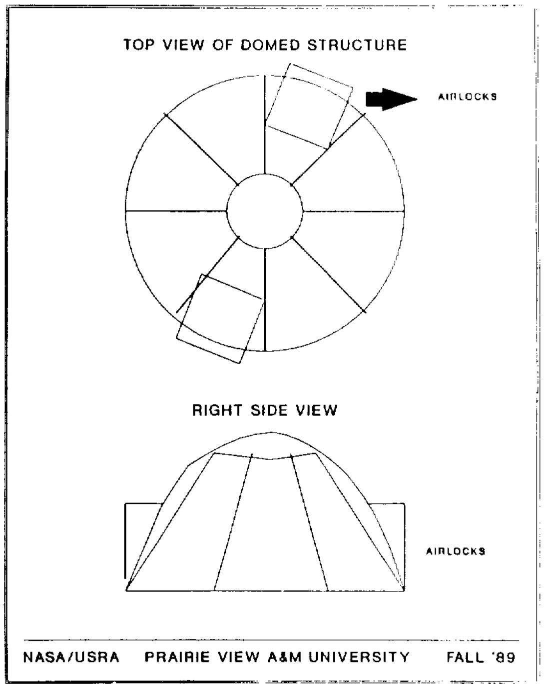

Fig. 1. Greenhouse Structure

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SITE SELECTION

The site chosen for the greenhouse is the Tharsis plain on Mars. The site, located between latitudes 0° and 20° and longitudes 60° and 120° East, satisfies the criteria of soil stability, area for expansion, nonundulating terrain, and infrequent sandstorm activity.

MATERIALS OF CONSTRUCTION

Lightweight materials resistant to radiation with high strength and low deformability are criteria for construction materials for the greenhouse. The materials should also be able to withstand pressure differences between the interior and exterior surfaces of the facility.

Fiber reinforced plastics (FRPs) will be used. These are classified in five main groups: (1) nylons, which are long strands of amines and are formed by reacting a diacid with a diamine; (2) acetals, which are compounds formed from a diethyl aldehyde base, and polyester resins, which are produced by reacting phaltyhalic acid with glycerol; (3) polycarbonates, which are formed from chains of carbonates; (4) blends of polystyrene, which are compounds formed from chains of styrene or phenylthylene and (5) polyphenylene oxides.

RADIATION SHIELDING

The objective is a feasible plan that will protect humans and plants from martian radiation.

Criteria

1. The shielding should protect humans and plants from radiation.
2. The shielding should be incorporated into the structure.

CONSTRUCTION METHODS

Another focus of this project was to investigate the methods that might be useful in the construction of the greenhouse. One method being investigated for lifting is via airbags. As illustrated in Fig. 2, a panel is laid across the airbag and air is released from the tank into the bag. As the bag is inflated, the panel is slowly raised upward into position. Once the bag is filled, the air tank is removed and a support is added to hold the panel in place while it is being fixed into the foundation of the greenhouse. The procedure is repeated until all of the panels are in place.

Since there will be limited manpower during the building of the greenhouse and other habitation facilities on Mars, construction using robots is also being investigated. Robots will be able to perform such maneuvers as lifting, drilling, hammering, etc.

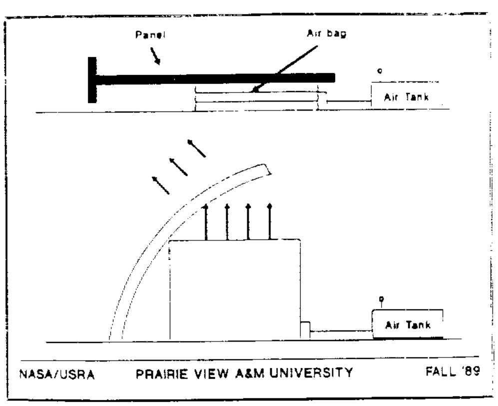

Fig. 2. Construction Method

ENVIRONMENTAL CONTROL

The development of a conditioning system for soil-grown plants is one of the goals of the environmental controls group. Plants will be grown on a conveyor belt system, which will allow for easy rotation of crops into the room where they receive nutrients.

This system must have the capability to monitor and control environmental conditions in addition to light such as humidity, temperature, oxygen and carbon dioxide levels, pressure, water tension in the soil, and presence of metabolites or toxicants.

The entire system is composed of a recognition device, a computer, and an automated pumping system (Fig. 3). The recognition device was modeled after the bar coding technique currently used on packaged grocery items. The code for each crop will be different. The plant's moisture, nutrient, and light content requirements will be coded and stored by the computer.

Another element is a control feedback loop that will consist of the following components: a process, a measuring sensor and transducer, a controller, and a final control element with the associated electropneumatic converter and transmission lines for the process measurement and the control command signal.

The final stage of the conditioning process will be the activation of an automated pumping system to open the valves of the nutrient pipes. Once the crop has been properly

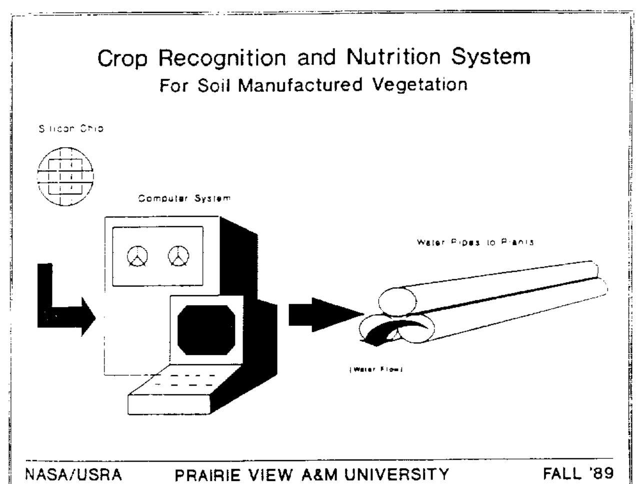

Fig. 3. Crop Recognition and Nutrition System

identified, the computer will instruct the valves of the pipes that contain the required nutrients to open, allowing the nutrients to flow into the water supply. The process will be timed according to individual crop needs. Once the nutrients have been dispersed, the system will shut itself off and prepare for the next crop on rotation.

SOIL INVESTIGATION FOR STRUCTURAL FOUNDATION

Subsoil explorations, referred to as site investigation, soil, and foundation investigation, are to determine the engineering properties and conditions of the soil and rock below the surface.

In order to provide economical construction and maintenance to minimize costly failures, overdesign, or overruns, a design based on an adequate foundation investigation and information about the nature of soil is necessary. The best way to obtain this information is to plan and execute a subsoil investigation to provide an efficient and cost-effective design.

The Planning Process

Soil explorations are conducted to verify information from surface examinations (see Fig. 4). The objectives of the soil investigation are: (1) to determine location, depth, thickness, and extent of each soil layer including description and classification of the soil and geology of the bedrock; (2) to determine the depth and characteristics of groundwater; (3) to determine the nature of soil and its stratification; (4) to obtain disturbed and undisturbed soil samples for visual identification and appropriate laboratory test; (5) to perform permeability tests, Van shear tests, and standard penetration tests; and (6) to make drainage calculations.

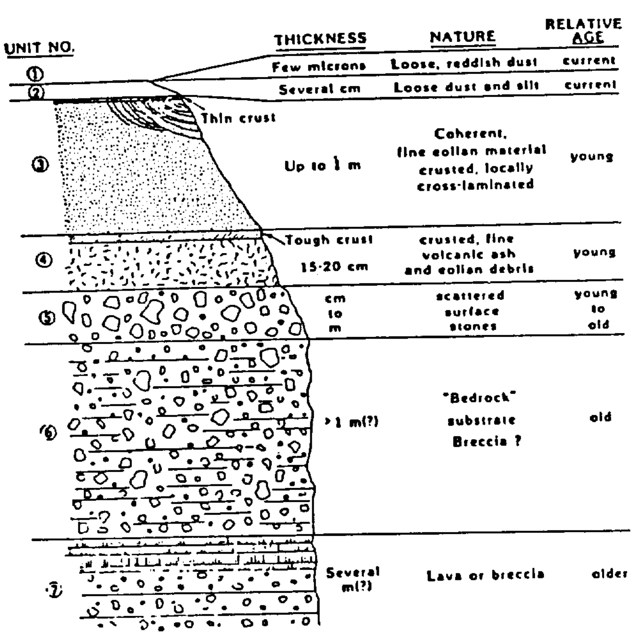

Fig. 4. Soil Profile of Mars

STORAGE TANK AND PIPING FOR HYDROPONIC SYSTEM ON MARS

The purpose of this design project is to investigate and analyze the design of a storage tank and the pipeline layout for a hydroponic system to be used on Mars. The objectives include: designing a piping system that will supply a flow of nutrients for each plant; designing a storage tank that can hold the volume needed; and selecting a pump that will provide adequate flow of water.

The project involves chemical, mechanical, and civil engineering. With the information and design analysis from all three, a functional hydroponic system can be designed for Mars.

Hydroponics

Hydroponics is a method of growing plants without soil. The plants are grown in an inert supporting medium, deriving their water and nutrients from a solution in the base of the container. The main benefit of the system is that the frequency of maintenance can be drastically reduced.

Plant Production

Plants can be grown in hydroculture from the earliest stage by germinating seeds or root cuttings in loose open materials like Perlite, frit, or cubes of polyurethane foam. The rooted cuttings are then placed into special plastic pots that have slitted or mesh sides to allow for the circulation of the hydroculture nutrient solution.

After planting, the pots are usually placed in raised troughs assembled from precast concrete units and lined with polyethylene sheets. The troughs contain about 50 mm of water circulated by pumps to aerate and mix the nutrient solution, as well as to control the water level.

The development of roots submerged in the nutrient solution is restricted by the low solubility of oxygen (8 ppm, by weight). Research has shown that growth is optimized at twice this level, which demonstrates the advantage of aerating the system. Jetting the circulated nutrient solution back into the production troughs can stimulate root growth in some species by up to 20%. Such an expensive procedure is not always necessary, as root development in many species is sufficiently rapid without the benefits of aerated water.

Hydroponic Systems

With large hydroponic systems, it is often necessary to pump the nutrient solution to different stories within a building. Pumps to achieve the necessary lift with a gravity cascade system for return may be used. Submersible pumps are proving to be of considerable advantage because of their ease of installation.

The time required to fill each trough completely will be one hour. The system is designed to continue to pump water in order to keep oxygen for the plants; however, the water level will remain stable.

The materials used for the design will be aluminum for the vessel pump, and PVC plastic for the pipe. These materials will allow for easy transportation because they are light and corrosion-resistant.

There is little chance of overflow because the design incorporates spillways, glove valves, and computer control (Fig. 5).

After six weeks, the system will be completely turned off for cleaning and restarted with fresh water as well as new soil medium.

This design will provide an efficient supply of food on Mars.

RECOMMENDATIONS FOR FUTURE RESEARCH

Plans for future research are the conceptual development and detailed design of all aspects of the colonization of Mars including the following:

1. Fish and poultry farm on Mars for life support
2. Mining of ores
3. Manufacturing of drilling tools
4. Use of robots for farming
5. Power generation system
6. Manufacturing of motors, batteries, and computers

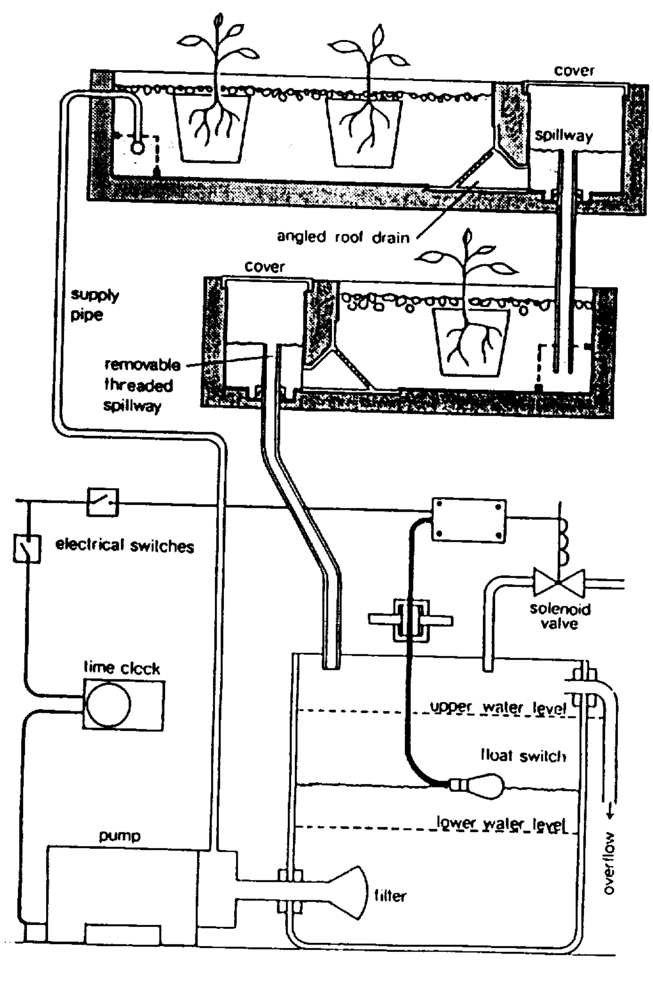

Fig. 5. Hydroponic System Design

ACKNOWLEDGMENTS

The College of Engineering and Architecture at Prairie View A&M University has been participating in the NASA/USRA Advanced Design Program since 1986. Recently, Prairie View was selected for continued participation in the program for the academic years 1989 through 1992. The university is also coordinating design activities through the new Texas Space Grant Consortium. The program, which is an interdisciplinary effort, involves students and faculty throughout the College of Engineering and Architecture. The students are actively involved in design projects related to space under the supervision of Dr. K.M.A. Rahman, Chairman of the Civil Engineering Department, Dr. R. Radha, Assistant Professor of the Civil Engineering Department, Dr. Ken Walter, Associate Professor of the Chemical Engineering Department, and graduate engineering student, Danette Willis-Reynolds.